(2)

NAMRL 1309

AD-A150 687

INTERFERENCE EFFECTS OF VOCALIZATION ON DUAL TASK PERFORMANCE

J. M. Owens, L. S. Goodman, and M. J. Pianka

September 1984

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

Approved for public release; distribution unlimited.

INTERFERENCE EFFECTS OF VOCALIZATION ON DUAL TASK PERFORMANCE

J. M. Owens, L. S. Goodman, and M. J. Pianka

Naval Air Systems Command
61153N WR04210 WR0421001-6142

Reviewed by

F. E. Guedry, Ph.D.
Senior Scientist

Approved and Released by

W. M. Houk, CAPT MC USN
Commanding Officer

September 1984

Naval Aerospace Medical Research Laboratory
Naval Air Station, Pensacola, Florida 32508

SUMMARY PAGE

THE PROBLEM

Voice command and control systems have been proposed as a potential means of off-loading the typically overburdened visual information processing system. However, prior to the introduction of novel human-machine interfacing technologies in high workload environments, consideration must be given to the integration of the new technologies within existing task structures to ensure that no new sources of workload or interference are systematically introduced. This study examined the use of voice interactive systems technology in the joint performance of two cognitive information processing tasks requiring continuous memory and choice reaction wherein a basis for intertask interference might be expected. Stimuli for the continuous memory task were presented aurally and either voice or keyboard responding was required in the choice reaction task. The effects of intertask stimulus similarity on multitask performance were also examined.

FINDINGS

Performance was significantly degraded in each task when voice responding was required in the choice reaction time task. Performance degradation was evident in higher error scores for both the choice reaction and continuous memory tasks. Performance decrements observed under conditions of high intertask stimulus similarity were not statistically significant.

RECOMMENDATIONS

The results signal the need to consider further the task requirements for verbal short-term memory when applying speech technology in multitask environments. Research should be directed toward identifying other potential sources of intertask interference with information processing to assist system task integration, function allocation, and the introduction of novel human-machine interfacing techniques in high workload, multitask environments.

INTRODUCTION

Modern, high speed aviation weapon systems impose complex information processing and workload demands on operators. Demands on the human visual-manual input-output system are especially extreme and may compromise operational system effectiveness through operator induced errors. Voice command and control systems have been proposed as a potential means of off-loading the typically overburdened visual information processing system. However, prior to the introduction of novel human-machine interfacing technologies in high workload environments, consideration must be given to the integration of the new technologies within existing task structures to ensure that no new sources of workload or interference are systematically introduced. Because of the complex psychomotor and cognitive requirements of the high workload environment of interest, viz., the cockpit, the integration of verbal and manual control tasks is of particular concern.

In a review of the literature on the concurrent performance of verbal tasks and manual tracking tasks, Harris (1) noted the lack of an adequate data base to support the integration of voice technology within multitask environments. Harris recommended a comprehensive, systematic research program to identify performance capabilities and limitations in concurrent verbal and manual control tasks. In a general sense, the concern is whether new human-machine interfacing techniques can faciltate system performance by utilizing relatively unused input and output channels, such as hearing and speech. Although no comprehensive data base exists, several studies (3, 4, 5) have provided support for the notion that the auditory input and speech output channels can serve effectively as additional, parallel means of information handling when the visual input and manual output channels are occupied with the processing of spatial information. However, other studies (2) have failed to provide support for that claim. Resolution of these discrepancies may result from a better understanding of the strategies that subjects employ in multitask situations (Damos, Note 1), of the relationship between the information processing requirements of the constituent tasks in the multitask environment (6), and of the unique processing requirements of each task considered separately.

A study by Harris, Owens, and North (2) addressed the latter point. The authors employed a multitask situation consisting of the concurrent performance of a manual tracking task and a digit processing task that required the continuous use of short-term memory. When keyboard responding was required in the latter task, auditory presentation of stimuli resulted in performance which was superior to that obtained with visual presentation of stimuli. When voice responding was required, visual presentation was superior to that obtained with auditory presentation. The authors hypothesized that this stimulus-response mode interaction resided in the peculiar information processing requirements of the digit processing task, viz., that the requisite rehearsal and

retrieval processes were more susceptible to disruption by intervening vocal responses than by manual responses.

The purpose of the present investigation was, in a general sense, to explore sources of potential interference when voice input/output (I/O) systems are employed in high workload environments. The specific purpose of the study was to examine further the effects of stimulus and response characteristics on memorial processes in multitask settings. Two cognitive tasks, a continuous memory digit processing task and a choice reaction time (CRT) task, were employed to represent typical kinds of information processing required of operators in high workload environments. To determine if the response requirements of the CRT task interfered with information processing in the digit processing task, stimuli in the latter task were always presented aurally, while the CRT task required voice responses in one condition, and keyboard responses in another. In addition, intertask stimulus similarity was manipulated by using visually presented digits in one CRT task condition, and colored lights in the other. Specifically, it was hypothesized that due to the auditory properties of human short-term memory (e.g., subvocalization in rehearsal) and the interference effects of highly similar items, performance on the tasks would be most disrupted when the CRT task required voice responses and digit processing.

METHOD

SUBJECTS

Twenty-four, right-handed, male student naval avaiators between the ages of 22 and 25 years participated as subjects in the experiment.

EXPERIMENTAL DESIGN

Subjects were tested in single and dual-task performance of both a continuous memory digit-processing task and a four-alternative, visual choice reaction time task. Stimuli for the digit processing task were presented aurally and required button-press responses in all experimental conditions. Intertask item similarity was a between subjects variable, (color versus digits), while the response mechanism required in the choice reaction time task was a within subjects variable (voice versus keyboard).

The nine experimental conditions described in Table I were used to form the test orders listed in Table II.

TABLE I

Experimental Conditions

1KS	single-task, digit processing, keyboard response
1KD	single-task, choice reaction, digits, keyboard response
1VD	single-task, choice reaction, digits, vocal response
1KC	single-task, choice reaction, colors, keyboard response
1VC	single-task, choice reaction, colors, vocal response
2KD	dual-task, digit choice reaction stimuli, keyboard response
2VD	dual-task, digit choice reaction stimuli, vocal response
2KC	dual-task, color choice reaction stimuli, keyboard response
2VC	dual-task, color choice reaction stimuli, vocal response

TABLE II

Test Orders

Order #1	1KS	1KD	2KD	1VD	2VD
Order #2	1KS	1VD	2VD	1KD	2KD
Order #3	1KS	1KC	2KC	1VC	2VC
Order #4	1KS	1VC	2VC	1KC	2KC

Six subjects were randomly assigned to each order to counter balance response mechanism within each of the two intertask item similarity conditions. At the start of the experimental session, the speech recognition device was trained to each subject's voice. Training consisted of having the subject repeat each possible reponse in the choice reaction task ("one", "two", "three" and, "four" for half the subjects; "red", "yellow", "blue" ,and "white" for the other half) ten times with the speech recognition device in its training mode. Single task conditions consisted of fifty stimulus presentations; dual task conditions consisted of 100 stimulus presentations, 50 for each task. Conditions were separated by 5-min rest periods.

APPARATUS

The subject was seated at a performance console in a sound attenuated booth which was separated from the experimenter's control station. Stimulus sequences were controlled by a Data General Corporation Nova 800 minicomputer with 32k x 16 memory. A custom-built interface received and decoded switch closures from the keyboard used by the subject and transmitted codes to the Nova computer.

Voice recognition of subject responses and voice synthesis of the absolute difference task stimuli were performed by a Scope Electronics Voice Data Entry Terminal System (VDETS) which consisted of a Data General Corporation Nova 2/10 minicomputer with 16k X 16 core memory, a Scope user's station, a voice synthesizer, and an ASR-33 teletype. The Nova 2/10 was hosted by the Nova 800. The Scope user's station converted voice analog signals from a microphone mounted on the subject's headset to digital format for entry into the Nova 2/10. A Vocal Interface Division Model VS-6 VOTRAX voice synthesis unit provided auditory output signals to the subject's headset in the testing booth. The teletype was used by the experimenter to control and monitor the VDETS utterance recognition performance.

The keyboard for the digit processing task was positioned on the left side of the console and arranged in a single horizontal row of four buttons labeled "1", "2", "3", and "4". The precontact travel of the microswitches was approximately 1mm.

The keyboard for the visual four-alternative CRT task was positioned on the right side of the console and was arranged in a horizontal row of four microswitches. From left to right the labels "red", "yellow", "blue", and "white" were positioned above the switches. In addition, the labels "1", "2", "3", and "4" were positioned from left to right below the switches.

The stimuli for the CRT task were presented via an IEE, one-plane readout which was located at a point 20 degrees of visual angle below the subjects eye level and directly above the choice reaction task keyboard. The projection surface of the readout was illuminated under computer control with either a red, yellow, blue or white light in one condition, or with the projected image of the numeral 1, 2, 3, or 4 in the other.

PROCEDURE

<u>Single Task Digit Processing</u>. In this self-paced task the subject was required to compute the absolute difference between two sucessive digits presented in a pseudo-random sequence. Stimulus digits varied between zero and nine. As soon as the subject responded with the absolute value of the difference between the current digit and the previous digit in the sequence, a new digit was presented. An example of a typical presentation sequence and associated responses is given below:

stimulus sequence: 7-4-8-6-3-1-0.....

subject responses: 3-4-2-3-2-1-.....

Stimulus presentation was arranged such that only the digits one through four were possible correct responses. In the event the subject forgot the previous stimulus digit, he could request that it be repeated by saying "again", whereupon the stimulus was repeated. If the recognition system failed to understand the subjects response, the subject was notified through the VOTRAX unit with the phrase "say again", whereupon subjects repeated their response. Response times on correct trials and number of errors were recorded for each of 50 test trials.

Single task choice reaction time task. In this experimenter paced task, the subject was required to respond to visually presented stimuli (colors or numerals). After a variable foreperiod of either 0.5, 1.0, or 1.5 seconds, the stimulus was turned on and remained on until the subject responded or 350 msec had elapsed. If the subject failed to responsd within 2000 msec or made an inaccurate response an error was recorded. The stimuli, the numerals 1,2,3 and 4 in one condition, and the colors red, yellow, blue, and white in the other, were presented in a pseudo- random order. Response times on correct trials and number of errors were recorded for each of 50 test trials.

Dual task condition. Following a variable foreperiod as above, the choice reaction stimulus was turned on for 350 msec. As soon as the subject responded, or 2000 msec had elapsed, the digit processing task stimulus was presented by the VOTRAX. As soon as the subject responded to the digit processing task stimulus the next choice reaction stimulus was presented. After the first trial there was no variable foreperiod in the CRT task; the onset of choice reaction task stimuli immediately followed a response to the digit processing task. The sequence was repeated for a total of 100 stimulus presentations, 50 for each task, during each dual-task session.

RESULTS

Single task trials were regarded as practice and were not considered in the following analyses. Total number of errors and correct response latencies were averaged across subjects within cells and examined separately for each task performed under dual task conditions. Split-plot two-way analyses of variance were used throughout. For CRT task performance, neither the main effect for intertask stimulus similarity, nor the interaction between stimulus similarity and response mode, were significant for errors ($F(1,22)=1.904$, $p > .05$ and $F(1,22)=1.32$, $p > .05$), or for correct reponse latency ($F(1,22)=0.112$, $p > .05$ and $F(1,22)=3.052$, $p > .05$). However, the main effect of response mode was significant for both number of errors, $F(1,22)=11.88$, $p < .01$ and correct response latency, $F(1,22)=21.483$, $p < .01$. From Figures 1 and 2, it can be seen that errors and response

latencies were greater in the CRT task when voice responding was required. An important qualification is discussed below in relation to the latency data obtained in the voice response mode.

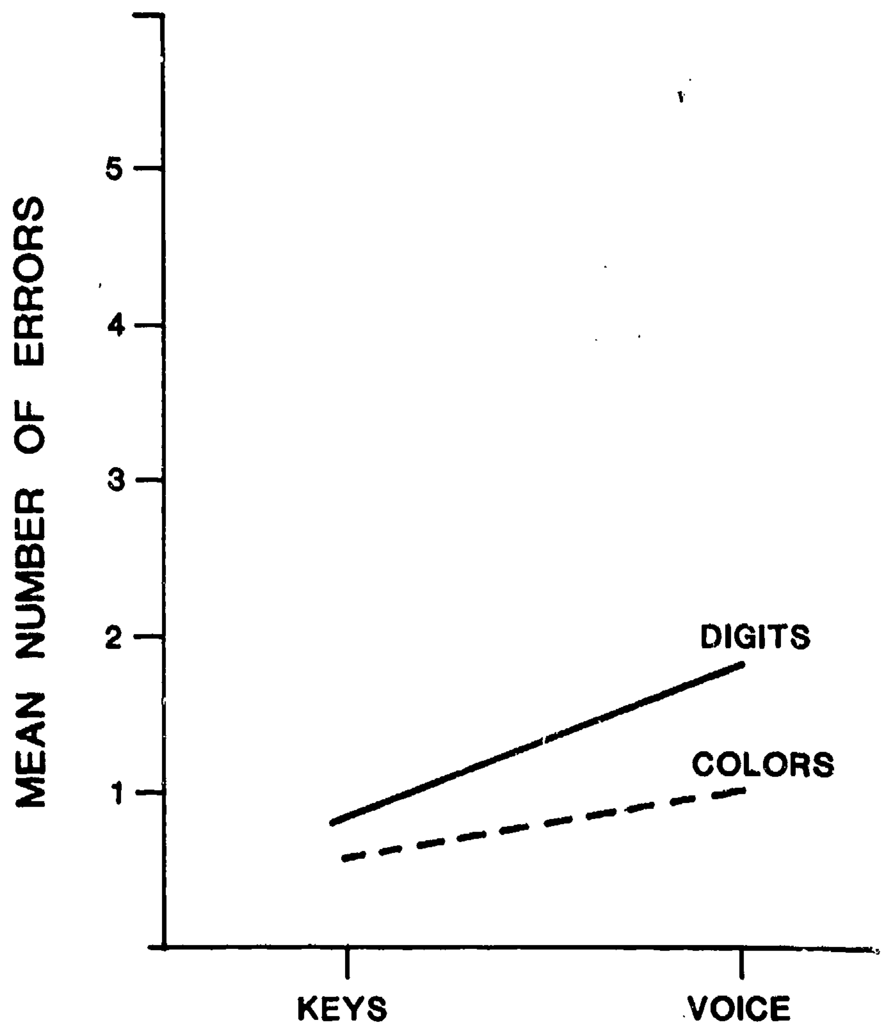

Figure 1. Mean number errors in the choice reaction task as a function of response modality.

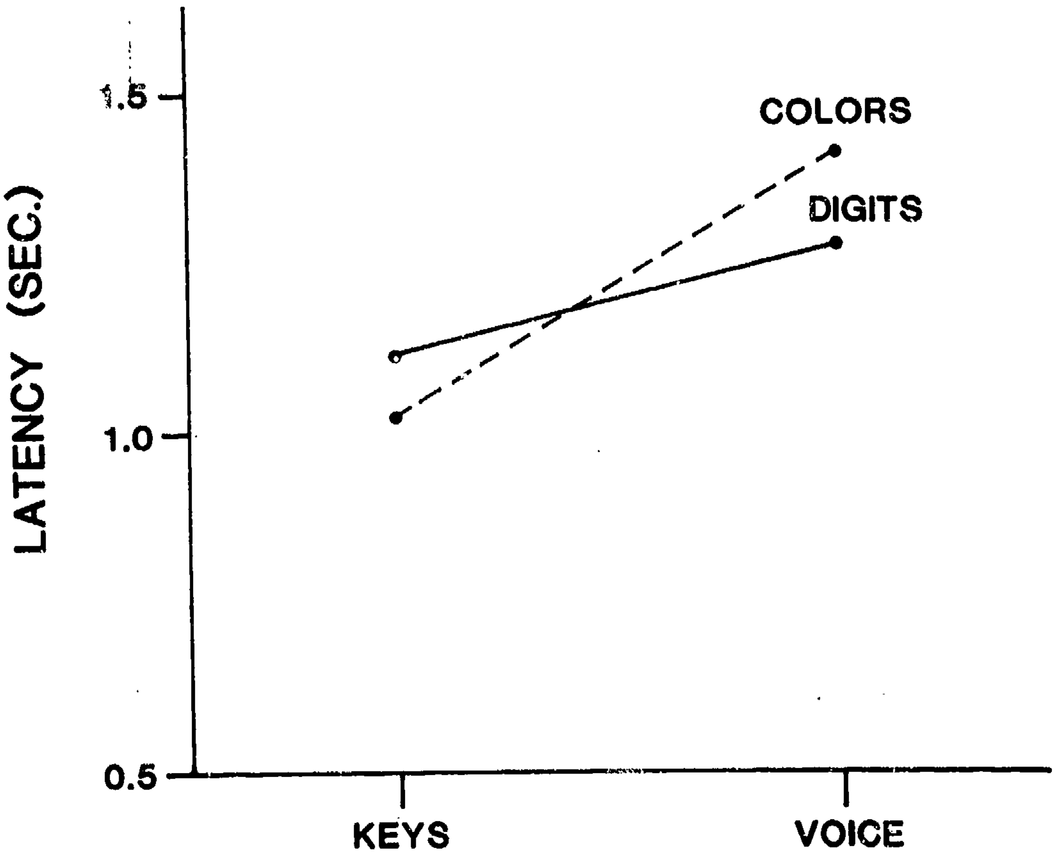

Figure 2. Average correct response latency in the choice reaction task as a function of response modality.

For continuous memory digit processing task performance, neither the main effect for stimulus similarity nor the interaction between stimulus similarity and response mode, were significant for errors ($F(1,22) = 1.627, p > .05$ and $F(1,22) = 2.433, p > .05$), or for correct response latency ($F(1,22) = 0.115, p > .05$ and $F(1,22) = 0.001, p > .05$). In addition, the main effect of response mode was not significant for correct response latency ($F(1,22) = 0.176, p > .05$). The response mode main effect was significant for number of errors, however ($F(1,22) = 4.525, p < .01$). As shown in Figure 3, more errors occurred in the digit processing task under conditions requiring voice responding.

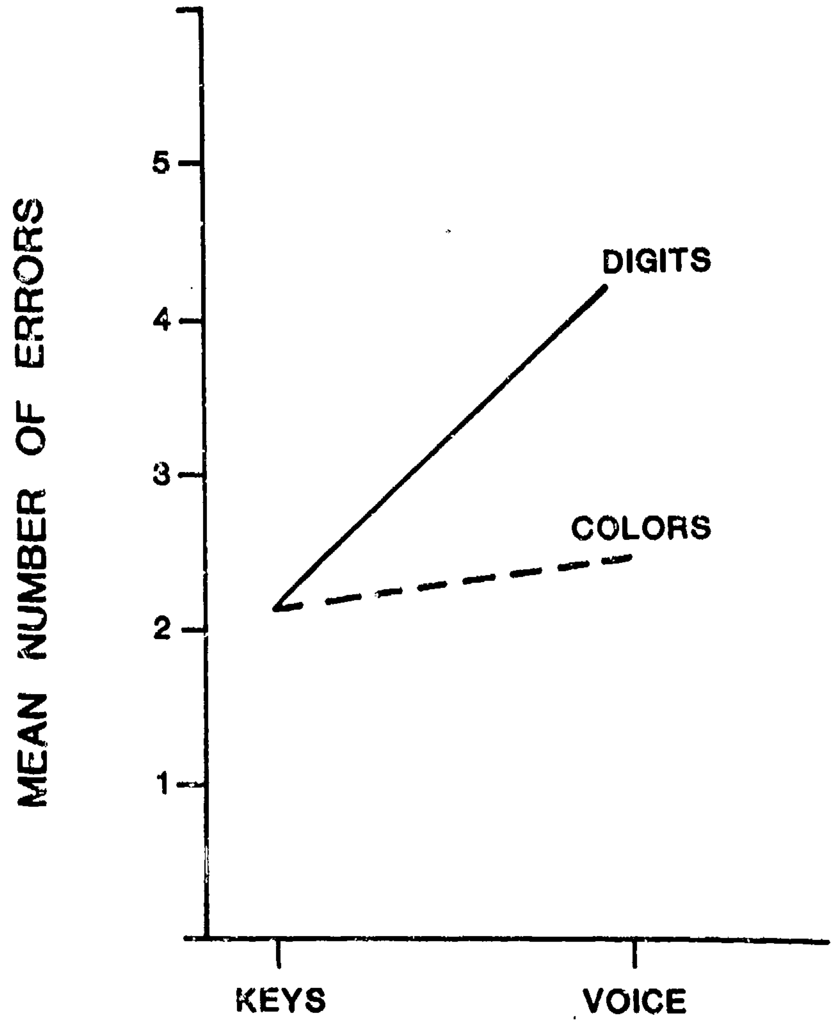

Figure 3. Mean number errors in continuous memory digit processing task as a function of response modality.

DISCUSSION

The results indicate that performance on each of the tasks was degraded when voice responding as opposed to keyboard responding was required in the CRT task. Performance degradation was evident in higher error scores for both the CRT and digit processing tasks. Although the results revealed that keyboard

responding was faster than voice responding in the CRT task, this finding must be interpreted with due consideration of the processing characteristics of the VDETS. The latency data for the CRT task represented the elapsed time from the onset of the stimulus to the completion of a correct response. In the voice response mode this time included, on the average, slightly over 500 msec required by the VDETS to accomplish utterance recognition. Thus, from the mean latency data shown in Figure 2, it can be seen that voice responses were actually initiated faster than keyboard responses. For present purposes, the latency data from the CRT task should not be interpreted as providing clear evidence of the superiority of either the voice or keyboard response modes.

Although intertask item similarity produced no statistically significant effects, differences in performance when digits as opposed to colors served as stimuli in the CRT task were in the predicted direction. More errors occurred, especially in the digit processing task, when digits were presented in the CRT task. The present investigation clearly did not represent a definitive attempt to explore fully the effects of intertask stimulus similarity on multitask performance. Rather, this study sought to highlight the effects that subtle, often overlooked task variables can have on complex task performance and the need for designers and test and evaluation personnel to consider such factors in evaluating new technology that will ostensibly enhance human performance. Parametric evaluations are needed to assess intertask stimulus similarity and other characteristics of task structures that can differentially interfere with information processing in multitask situations, particularly those involving short-term memory requirements.

Overall the data suggest that the acoustical attributes of the stimuli and reponses in jointly performed tasks can give rise to intertask interference, especially when one or more of the tasks require rehearsal and retrieval from short-term memory. As inferred from previous work (2), it seems most likely that rehearsal and retrieval processes active during continuous memory task performance were more susceptible to disruption by intervening vocal responses than by manual responses. Specifically, these results signal the need to consider further the role of verbal short-term memory in applications of speech technology. In general, though, research concerning the efficacy of voice I/O for command and control operations should be directed toward identifying other potential sources of intertask interference with human information processing.

The implications of the present results for system designs that contemplate the use of voice interactive systems technology are seemingly straightforward. It is not simply a matter of determining if a function can be performed using voice I/O, but rather how well the function can be performed in the context of the total task ensemble. The possibility certainly exists that additional requirements for voice I/O could serve to deprecate overall performance in some competing task demand situations.

Such would be the case, for instance, during high workload, transition phases of flight in which verbal communication requirements are often greatly increased. Research that further delineates the loci and extent of interference effects of voice I/O in multitask situations should provide results very useful to system task integration, function allocation, and the introduction of novel human-machine interfacing techniques in high workload environments.

Reference Note

1. Damos, D. *The effects of asymmetric transfer and speech technology on dual task performance.* Manuscript submitted for publication, 1984.

REFERENCES

1. Harris, S.D. Human performance in concurrent verbal and tracking tasks: A review of the literature. Special Report 78-2, Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1978.

2. Harris, S.D., Owens, J.M., & North, R.A. Human performance in time-shared verbal and tracking tasks. NAMRL-1259. Pensacola, Fla.: Naval Aerospace Medical Research Laboratory, 1979.

3. Sandry, D.L., & Wickens, C.D. The effect of stimulus-central processing-response compatibility and resource competition on pilot performance. Engineering-Psychology Research Laboratory: University of Illinois at Urbana-Champaign, Report No. EPL-82-1/ONR-82-1, April, 1982.

4. Vidulich, M., & Wickens, C.D. Time-sharing manual control and memory search : The joint effects of input and output modality competition, priorities and control order. Engineering-Psychology Research Laboratory : University of Illinois at Urbana-Champaign, Report No. EPL-81-4/ONR-81-4, December, 1981.

5. Wickens, C. D. The structure of attentional resources. In R. S. Nickerson (Ed.) Attention and Performance VIII. Hillsdale, New Jersey: Lawrence Erlbaum Associates, 1980.

6. Wickens, C. D. Processing resources in attention, dual task performance and workload assessment. Engineering-Psychology Research Laboratory: University of Illinois at Urbana-Champaign, Report No. EPL-81-3/ONR-81-3, July, 1981.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAMRL– 1309	2. GOVT ACCESSION NO. A150687	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Interference effects of vocalization on dual task performance		5. TYPE OF REPORT & PERIOD COVERED Interim
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. M. Owens, L. S. Goodman, and M. J. Pianka*		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Aerospace Medical Research Laboratory Naval Air Station, Pensacola, Florida 32508-5700		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Naval Air Systems Command 61153N WR0421001-6142
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research and Development Command Naval Medical Command, National Capitol Region Bethesda, Maryland 20814		12. REPORT DATE September 1984
		13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Air Systems Command Code 330J Washington, D. C. 20361		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

*Current address for LCDR M. J. Pianka is Naval Air Test Center (Code SY70P), Patuxent River, Maryland 10670.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Voice technology
Dual task performance
Interference effects
Short-term memory

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Voice command and control systems have been proposed as a potential means of off-loading the typically overburdened visual information processing system. However, prior to ~~the~~ ~~introduction~~ ing of novel human-machine interfacing technologies in high workload environments, consideration must be given to the integration of the new technologies within existing task structures to ensure that no new sources of workload or interference are

DD FORM 1473 1 JAN 73 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. Abstract (continued).

systematically introduced. This study examined the use of voice interactive systems technology in the joint performance of two cognitive information processing tasks requiring continuous memory and choice reaction wherein a basis for intertask interference might be expected. Stimuli for the continuous memory task were presented aurally and either voice or keyboard responding was required in the choice reaction task. The effects of intertask stimulus similarity on multitask performance were also examined.

Performance was significantly degraded in each task when voice responding was required in the choice reaction time task. Performance degradation was evident in higher error scores for both the choice reaction and continuous memory tasks. Performance decrements observed under conditions of high intertask stimulus similarity were not statistically significant.

The results signal the need to consider further the task requirements for verbal short-term memory when applying speech technology in multitask environments. Research should be directed toward identifying other potential sources of intertask interference with information processing to assist system task integration, function allocation, and the introduction of novel human-machine interfacing techniques in high workload, multitask environments.